While the MSC switches the 911 voice call, TruePosition simultaneously processes the telephone's call origination message through its high-priority queues. Automatic Location Information (ALI) is determined for the 9-1-1 call and recorded within 5 seconds in a 911 location database in the Application Processor.

The 911 tandem switch holds the voice call temporarily while it queries the TruePosition 911 location database, using both the caller's ANI and cell site pseudo-ANI. After the 911 tandem obtains the caller's ALI (in latitude/longitude or other format) from TruePosition, the voice call and its ANI/ALI information is routed to the nearest responsible PSAP. The 911 tandem switch on the PSAP can then use the ALI data to query the MSAG and obtain the phone numbers for the closest police, fire, and medical agencies.

Even a sophisticated system like TruePosition cannot be 100% accurate all of the time. There are many potential error sources in a location system, including the electronic maps using on most computer terminals. Many of these error sources will be eliminated as location systems become more fully deployed, but even so, the rules issued by the Federal Communications Commission (FCC) make allowances for these statistical errors. By October, 2001, the FCC requires location systems to have an accuracy of 410 feet or better for every 67 out of 100 emergency calls. The other 33 out of 100 calls may have errors greater than 410 feet.

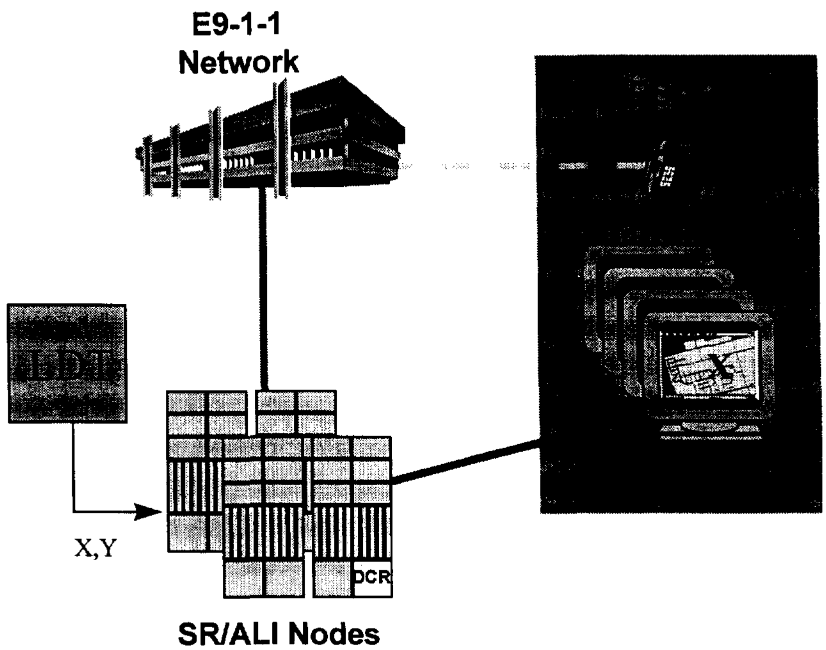
SCC Communications Corp.
Eric Sorensen

Wireless 9-1-1 presents new challenges to the existing E9-1-1 network. In most current E9-1-1 networks, call routing for each individual telephone number is pre-determined based on address/location information supplied by the local exchange carrier. Call routing and address/location information is then updated to databases that are then available for live 9-1-1 call processing. All initial database creation and ongoing maintenance is performed administratively in background modes.

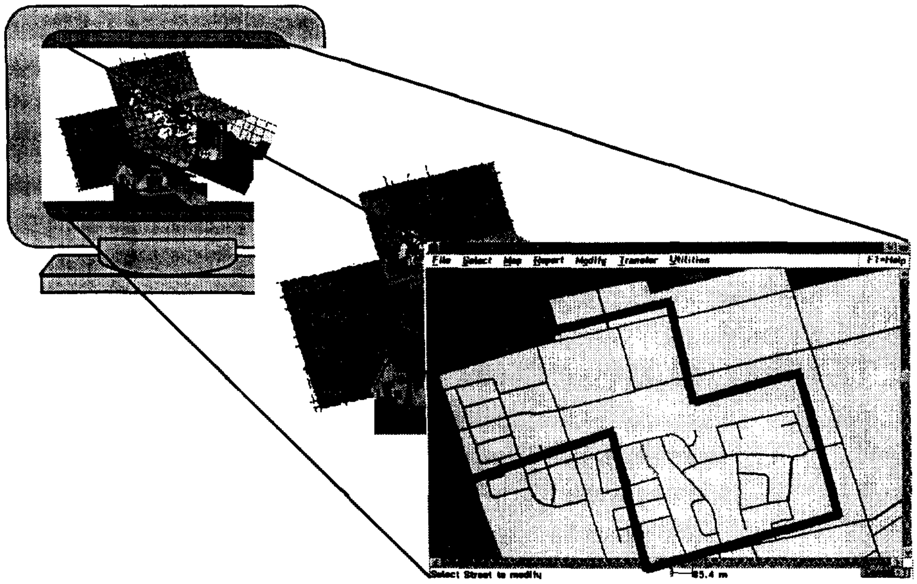
In the wireless world, it is not possible to predetermine the source location of a 9-1-1 call because the communication devices are always moving. For this reason, the traditional MSAG and preprocessed relational files can not be used. A geofile or map base must become the backdrop for routing decisions. As a coordinate pair is received from the location determination equipment, it is electronically plotted against the geofile to determine its relationship to PSAP boundaries. Routing instructions must be dynamically created in real time and provided to the E9-1-1 network during the call set up process. The coordinate data is then used to dynamically create an ALI record for distribution to the appropriate 9-1-1 call taker.

To support these new challenges in wireless 9-1-1 networking, SCC provided the Texas WIP with their SR/ALI platform, including their Dynamic Call Routing (DCR) feature. SCC's DCR application uses a "Point in Polygon" routine for calculating the Dynamic Emergency Service Number (DESN) which will be used to provide routing instructions to the E9-1-1 network. The SR/ALI product is compatible with all current E9-1-1 selective routing switches. For the Texas WIP, it was interfaced with a Lucent 5E.

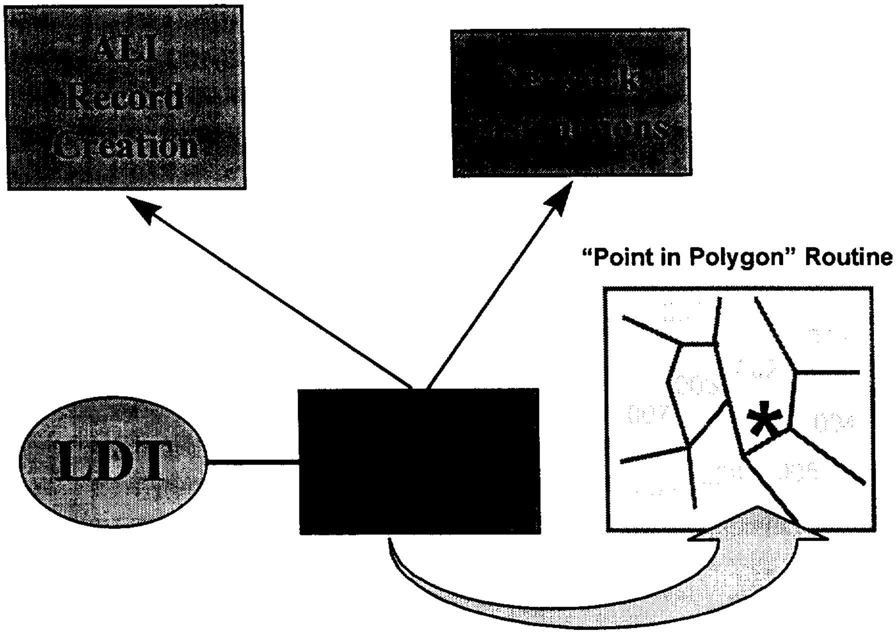
DCR Integration -
SCC's DCR application integrates with their existing SR/ALI platform for seamless operation between wireless and wireline E9-1-1 call processing.



Graphic MSAG Management (GMM) - SCC used their GMM product to convert a geofile provided by Tarrant County 9-1-1 to a DCR compatible file. This geofile defined the PSAP boundaries (ESNs) for the test area. This process provided the polygon layer for the "PiP" routine used in DCR.



Dynamic Emergency Service Number - The creation of a dynamic ESN is the result of matching the X,Y coordinate of the calling parties location with a polygon in the polygon layer in the "PiP" routine in the DCR application. An X,Y coordinate location will be matched with an ESN polygon layer and then translated into a dynamic ESN assignment for the cellular caller's location. This information is then provided to the SR/ALI platform where network call routing instructions and ALI records are dynamically created.


ALI Record Creation
"Point in Polygon" Routine
LDT

Southwestern Bell Telephone
Cindy Clugy, Ben Mahaffey, Ron Mathis

As a member of the project team, Southwestern Bell was extremely dedicated, bringing resources, equipment, and people to the Texas Wireless Integration Project (WIP).

For the Wireless Integration Project (WIP), Southwestern Bell provided:

- The 911 Selective Routing Tandem Switch
- Network Connectivity between the 911 Selective Routing Tandem, the End Office, the Selective Routing/Automatic Location Identification (SR/ALI) Database and the Test PSAPs.
- Network Connectivity between the Associated Group, Inc., Signal Collection System (SCS) and TDOA Location Processor (TLP).

Southwestern Bell's Houston Medical Center Central Office was selected to be the host switch for the 911 Selective Routing Tandem. The Medical Center Central Office is equipped with a Lucent 5 ESS Digital Switch. The Medical Center switch was selected because the Lucent 5ESS digital switch provides the ability to pass 10 digit ANI and most importantly it provided the ability to connect an optional Selective router via Attached Processor Interface (API) links.

The Medical Center 5 ESS switch is currently on software version 5E 10.1. Feature packages required in the Lucent 5 ESS digital switch for the Wireless Integration project were:

- Feature package #61 – Enhanced 911 Feature
- Feature package #116 – CPN Delivery on E911 Call feature

The Lucent 5ESS digital switch provided the ability to connect SCC's SR/ALI database to the 911 Tandem utilizing two (2) API links. These API links are basic rate interface (BRI) ISDN lines using X.25 Packet Switching over the D channel. A 7BDII Network termination from Lucent was required to terminate the BRI ISDN line at the SCC SR/ALI. The 911 Tandem queries to the SCC Selective Routing Database over the API links and receives the ESN assigned to the calling number.

Common Channel Signaling System 7 (CCS7) trunking was used to interconnect the end office, Houston Cellular MSC Switch #2, to the 911 tandem. With CCS7, Signaling and voice paths have been separated. Signaling is accomplished using the CCS7 protocol over high-speed data links.

Interconnection from the 911 Tandem to the test PSAPs was provided using two methods:

1. The Beta I PSAP, a NORTEL Meridian 1, Option 61 PBX was connected to the 911 Tandem utilizing National ISDN Standard (PRI) Primary Rate Interface. The ISDN PRI allows the 911 tandem office to pass the true ten-(10) digit ANI to the PSAP. The ANI or CPN (calling party number) field received over the CCS7 protocol from the end office is passed to the 5 ESS which in turn converts it to a Q.931 signaling protocol which is delivered over the ISDN PRI D Channel.

2. The Beta II and Village PD PSAPs, equipped with NORTEL Meridian 1, Option 11 PBXs, were connected to the 911 tandem office via standard CAMA trunks. The CAMA trunks transmit the ANI information to the PSAP in a standard inband, MULTI-Frequency (MF) pulsing, eight (8) digit format. The eight-(8) digit ANI format is the NPD digit, that represents the NPA and the seven-(7) digit calling party number.

Southwestern Bell provided 56 Kbps circuits from TruePosition's Signal Collection System (SCS) at eight Cell Tower sites to TruePosition's TDOA Location Processor. Southwestern Bell also provided 1.2 Kbps circuits from the PSAP's intelligent workstations (NORTEL Visit ENR) to the SCC SR/ALI, to receive the caller's location information.

Several issues were identified during the testing phase of the Wireless Integration Project. These issues are discussed below:

Timing interval between the 911 tandem query from the Lucent 5ess Digital Switch to SCC's SR/ALI database and the timing interval of the delivery of the callers location (Latitude and longitude) provided by the TruePosition's Time Difference of Arrival (TDOA) location processor (TLP) to the SCC SR/ALI Data Base

It was discovered during the testing that SCC's SR/ALI database would receive the selective routing query from the Lucent 5 ESS Digital Switch on average 1.5 – 3 seconds before receiving the callers location (Latitude and longitude) from TruePosition's TLP.

Different methods were tried to introduce delay in to the call processing before the 911 tandem switch would send it's selective routing query to SCC's SR/ALI database. These methods included attempting to add delay at the end office.

Houston Cellular MSC #2 switch. The Houston Cellular MSC #2 is equipped with an Ericsson Digital switch. Attempts to add delay to the call processing in the Ericsson Digital Switch were unsuccessful. Several attempts were made to add delay at the 911 Tandem, Lucent 5 ESS Digital switch, on the incoming trunk group translations. On normal CAMA trunking between the end office and the 911 Tandem office you can add delay by having the incoming trunk translations wait for additional dialed digits. This failed to work in this trial due to using CCs7 Signaling between the end office and the 911 tandem office. All dialed digits are carried in the Called Number field of the CCS7 protocol. The 911 tandem received all dialed digits at the same time. Additionally, at the 911 tandem, an AIN (Advanced Intelligent Network) trigger was placed on the incoming 911 trunks from the end office in an attempt to add delay. Although this method seems to be the best chance for success it also failed.

Additional research is needed to address this timing issue.

The next issue involves the ANI/CPN delivery from the end office to the PSAP's.

It was found that via CCS7 Signaling from the end office to the 911 tandem, CCS7 protocol would deliver the true ten (10) digit ANI/CPN to the 911 tandem. The 911 tandem would then take the ten (10) digit ANI from the CPN field of the CCS7 protocol and send the ANI to the PSAP's. The 911 tandem switch would successfully transmit the true ten (10) digit ANI from the CCS7 protocol to a PSAP connected to the 911 tandem via ISDN PRI trunking.

It was found however that when the PSAP was interconnected to the 911 tandem via standard CAMA trunks that the 911 feature translations in the tandem switch would determine the NPA from the trunk group translations.

This means that if the trunk group is identified as a 713 trunk group the 911 feature translations would take the seven (7) digit calling number from the CCS7 protocol and assign a NPD digit from the trunk group to fill the eight (8) digit ANI format for CAMA trunks. When any other NPA caller would place a call, the following failure would occur. Example: 281-123-4567 would dial 911 from the end office, the CCS7 protocol would send 281-123-4567 to the 911 tandem office in the calling party number (CPN) field. The 911 tandem office would then query the SR/ALI database for the ESN assigned to 281-123-4567. Receiving the ESN the 911 tandem would then route the call to the PSAP. However, because the PSAP was interconnected to the 911 tandem via CAMA trunks, the 911 tandem would take the seven digit calling number (123-4567) and assign a NPD based on the trunk group translations (NPD 0 = NPA 713) and send 0-123-4567 to the PSAP.

The PSAP identifies NPD 0 as 713 and has now identified the calling number incorrectly as 713-123-4567. This would cause ALI failure at the PSAP, when the PSAP would query the ALI database for the location of 713-123-4567.

Additional research is needed to address this issue.

The next issue involves the delivery of a call from the 911 tandem to the PSAP via ISDN PRI trunking.

When a call is delivered to a PSAP via ISDN PRI trunking, the PSAP does not have the ability to use the selective transfer functions of the 911 tandem to transfer a call from that PSAP to another PSAP or seven (7) and ten (10) digit numbers. The 911 tandem has released call control to the PBX when the call is delivered to the PSAP over the ISDN Primary Rate Interface.

Additional research is needed to address this issue.

Any questions or requests for additional information may be directed to:

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Map Base Rectification

Mapping Results of the Wireless Integration Project

Tarrant County 9-1-1 District
Beth Ozanich

Spatial Data Research, Inc.
Keith W. Cunningham, Investigator

Overview

An accurate and complete map is critical to the successful implementation of any location determination technology (LDT) to locate wireless 9-1-1 calls. The map serves as a positioning reference tool and graphically communicates the location of the person reporting an emergency. Thus, the map is the tool which interfaces the LDT to the dispatcher. An inaccurate or incomplete map will likely provide inaccurate and incomplete dispatch information. Producing an accurate map to support the Wireless Integration Project (WIP) was a requirement defined early in this project and is the principal topic of this paper.

The science and art of mapping has undergone a tremendous change over the past decade. Digital mapping has been transformed from an esoteric science of computer programming and photogrammetric engineering, into a layperson's toy popularized by off-the-shelf mapping systems and public domain mapping databases. This revolution in mapping access has removed the knowledge and training previously required to build accurate and complete maps for their intended purpose. Now maps are being used incorrectly and for inappropriate applications by users who are not even aware of these issues. This problem applies to 9-1-1 emergency dispatch and now to the integration of LDT with wireless call tracking.

Several issues must be considered in the integration of digital mapping with LDT. Perhaps the greatest and most overlooked issue is how does a dispatcher who is not experienced with mapping, relate with the information presented on the map. The cognitive interface of any mapping system requires ambiguous communication of information, especially during the stress and limited time available during emergency dispatch.

The WIP created many other issues deserving greater research than was envisioned. Besides the cognitive or "human factors" relating to dispatch mapping, other issues were realized such as multi-jurisdiction dispatch, real-time event geocoding, and dynamic call routing. Fundamental issues of map coordinate systems were also raised.

Introduction to WIP Mapping

The mapping data available to the WIP included one of the most popular sources of digital mapping data, the TIGER Line Files. TIGER (Topologic Integrated Geographic Encoding and Referencing) is a public domain digital mapping database created by the Census Bureau for the 1990 Census. The source materials used in the construction of TIGER was the USGS 1:100,000 series maps whose nominal working scale is one inch representing the map equivalent of 1.578 miles. Obviously, at this working scale, there is not a lot of detail and any electronic representation of a map at this scale will have a significant amount of positional error. This positional error is often stated in terms of National Map Accuracy Standards (NMAS) which means that of the features digitized from source maps, 90 percent should be within 1/50th of the map's scale, or in the case of TIGER, 166.7 feet.

In urban areas, such as the WIP test area, the Census Bureau needed the attribute information, primarily address ranges, found in the cartographic data files compiled for previous decennial censuses, known as the GBF-DIME files. The GBF-DIME files were created to automate census questionnaire tabulation by matching census statistics to address ranges, street block sides and census blocks. The GBF (Geographic Base Files) used a two-address range approach (Dual Independent Map Encoding or DIME) to match census data to unique street sides. The positional accuracy of the GBF-DIME is actually coarser than the TIGER data, and often the information does not have the detail found in TIGER, because only streets with addressing were required to be cataloged. Today, the information content found in the GBF-Dime files is now found in the TIGER files.

As an emergency dispatch tool, the TIGER files have a both advantages and disadvantages. Among its advantages are its low cost, reasonable amount of completeness and accuracy, and that there is often no other readily available database for a community. Due to these advantages, TIGER often finds its way into many emergency dispatch applications.

As an emergency dispatch tool, TIGER has many shortcomings. In an urban area, the most obvious shortcoming is the lack of spatial accuracy, with many roads varying from true position by as much as 200 feet. TIGER also suffers from incomplete and inaccurate map features and supporting attribute information , such as road names and address ranges. It should be reiterated that TIGER was built to conduct a census, not dispatch emergency vehicles.

WIP Map "Accurizing"

The mapping source for the Wireless Integration Project is the TIGER data available for Houston delivered with the MapInfo software used by the Greater Harris County 9-1-1 Emergency Network. In Harris County, a region known as the Villages was selected for the pilot because of the density of cellular towers and variety of geographies including subdivisions, shopping malls, parks and an interstate corridor.

Several methods exist to update the source maps. To the layperson, perhaps the most obvious approach would be to re-digitize the road network from the USGS quadrangles. However, the quads for the region of the pilot study were created in 1976, and edited in 1982. Thus 20 years of updates would be necessary. Another, more professional option, is the use of aerial photography to update the road locations, however there are costs and delays in the acquisition of aerial photos as well as inherent distortions which would have to be reduced by photogrammetric techniques. If either of these methods of map update were used, the roads would still have to be field checked to update attribute information such as road names and addressing, because none of this information is present on the sources.

Since the field check is necessary, it was determined that differential GPS could be used to correct road locations. The use of differential GPS would also permit staff to immediately begin their work. The limitation of the GPS approach was that the positional data being collected dynamically may range in accuracies of five to seven meters (double distance root mean square (2dRMS), and less accurate positioning is possible about five percent of the time. These accuracies are about the same as the width of the roads being driven, thus the error was considered to be acceptable.

The "Accurizing" Process

Work commenced in the pilot area by setting up a GPS base station to collect GPS signals simultaneously with the GPS mounted on the vehicle used to drive and map the roads. The GPS data collected by the base station is used to remove intentional error in positioning introduced by the military and other error generated by the atmosphere.

Each work day lasted between ten and fourteen hours and GPS positions were collected every two seconds. This data collection rate accumulated over 18,000 GPS positions in a long day. Four and a half days of days of field work were conducted.

As each day's work was completed, the field data were differentially processed against the base station's observations to reduce positioning errors. Then the raw positions of latitude, longitude and heights were exported into an ASCII file for their eventual import into MapInfo.

At each recorded GPS position, a small circle was placed into a MapInfo workspace. The GPS positions generally followed the road locations found in the TIGER line files provided by MapInfo. The map on the previous page shows the TIGER roads as dashed lines. The revised road locations are the darker, solid lines.

Several types of map updates and corrections were required. The most commonly used map update method was to move a road intersection, which also updated most of the road network. Another type of update was an improvement in road geometry, thus improving the "shape" of the road to fit the GPS locations. A third update was the addition of new roads and connecting roads which did not connect with other road segments in the original maps.

Most of the updating consisted of moving road intersections that were offset from the recorded GPS locations. These were easily fixed by moving the road intersection node (the intersection of the roads) to the proper location. MapInfo maintained the connectivity of the road segments when making the adjustments.

The other common type of problem was inaccurately shaped roads. These problems included not enough bends or too many bends in a road . Most of the latter problems were fixed "for free" when the road intersection locations were adjusted. The other road shape problems were fixed by adding or deleting nodes and by moving nodes, thus changing the shape of the road.

In a few cases, a road segment not present in TIGER was added. Occasionally roads are shown to intersect by the GPS positions indicated by the vehicle's path of travel, but these roads did not connect in TIGER. These features were adjusted accordingly.

The above figure shows the typical amount of position displacement between the original map and the GPS-enhanced road positions. Displacement is often as large as 210 feet. Typically, however, positioning errors ranged from 70 to 110 feet, well within NMAS for digital data whose source is based on 1:100,000 scales sources. While some intersections and roads were found to be positionally accurate in the original data, these were very few.

Mapping Issues for LDT

A common problem associated with map use the near reverence people have for the mapped information. When the GIGO (garbage in, garbage out) phenomenon is applied to maps, people tend to interpret any "garbage" in the map as "gospel." This is important to LDT and map-aided dispatch because dispatchers must understand the inherent mapping errors. It should also be understood that maps and their sources are always incomplete and out of date due to the changing real world. More importantly, when a position is indicated on the map, the region where the LDT call could be located can be quite large, due to errors and uncertainties in the positioning technologies.

The technologies used in LDT can determine a position of a wireless call, but the accuracy of the position must be properly interpreted. Like all mapping and positioning technologies, the term accuracy means how closely repeated measurements of the same feature can be made. Accuracies in mapping are expressed in statistical terms which assume that position measurements fit a normal distribution (bell curve). Therefore, one may state that half of the observed positions may be within a specified accuracy. One standard deviation (root mean square or RMS), which represents about 65% of the observed positions is another statement of positioning confidence. The second standard deviation (double distance root mean square or 2dRMS) represents a 95% confidence in the accuracy of the positioning.

Presently, LDT positioning is estimated by manufacturers to be within 125 meters RMS. This means that one third of the 9-1-1 wireless calls may have positional accuracies worse than 125 meters (390 feet). This level of positioning confidence is thus about the length of a city block. Because of the statistical nature of these measurements, there could be a percentage of the 9-1-1 wireless call which could also be more accurate than a few feet. This is simply the statistics and apparent randomness of such measurements.

Two types of positional accuracies should be considered when using a LDT to map emergency calls. The first is the positional accuracy of the map and the second is the positional accuracy of the location reported by the LDT. Mapping accuracies have been rapidly improving over the past ten years and LDT positioning is also likely to improve considerably with its use. LDT positioning of about 40 meters RMS seems to be quite possible with today's technology. The following figure displays the positional accuracies of the map as well as 125 and 40 meter circles indicating the positional confidence of a wireless emergency call.

The WIP Map and Human Factors

Several issues must be considered when displaying the computed position of the cellular 9-1-1 call. The most important issue is that the map is an information communication tool. The objective of the map is to communicate information quickly and unambiguously to minimize human interpretation error.

One of the communication problems with the original TIGER data provided with MapInfo is the poor positional accuracy and random changes in shape of many roads. Reducing the geometric and spatial inaccuracies improves the human interpretation of the map.

Another key to the proper use and interpretation of the map should be a determination as what scale the map should be presented. Many problems with map positioning are simply overcome by decreasing the scale of the map. Decreasing map scale presents a larger area for viewing and hides positioning error via the map symbolization process. This technique minimizes the apparent error in TIGER and its random road changes in the GBF-DIME areas.

Elementary cartographic issues have not been researched for the user of emergency dispatch mapping systems. Research is needed to define standards for symbology, eye-strain, and scale-dependent abstraction for dispatch cartography.

More Esoteric Mapping Issues

Mapping Resolution and Error Budget

When building a map, especially a digital map, the scale (level of inherent mapping inaccuracy) of the mapping source must be remembered. The mapping accuracy of the raw TIGER data in MapInfo is approximately 166 feet for about 90% of the features and the accuracy of the GPS dynamically collected is 15 to 21 feet. Thus maps should not really be used for any applications requiring any greater degree of positional accuracy. Digital mapping technologies lure people ignorant of numeric and error analysis into believing that a map can be successively magnified while maintaining the same mapping accuracies and usefulness. This tends to be a problem with experienced map users and is a difficult concept to understand by novices.

The mapping resolution and error budget required for an efficient LDT are likely to be a few meters. This implies that the accuracy of the map should be about the same. However, when one considers that the typical 9-1-1 emergency call is likely to be made from a car or house, this requires resolution and mapping accuracy on the order of about three to five meters. Since emergency dispatch calls are being referenced to a road map, the required resolution then climbs to the width of the road or size of a home, which could range from seven to twenty meters.

These accuracies are perfectly acceptable outdoors. More accurate mapping and LDT information may be required if one wishes to dispatch to a complex indoor location like an apartment, shopping mall or office. In these cases we are no longer dealing with a digital map, but much more detailed drawings, floorplans and expensive databases.

Maps created for LDT can thus have a mapping resolution ranging from five to ten meters which means the level of mapping error, or budget, which is acceptable can be on the same level.

Map Coordinate Systems

One of the most intriguing issues faced by the display of a LDT position on a map is the question of mapping projections. Mapping requires a coordinate system which is used to reference the locations of mapped features. Mapping coordinate systems are selected to minimize different types of mapping errors. Some types of mapping errors include coordinate systems designed to preserve the true shape of features, while others preserve true area and distance measurements of features.

The coordinate system to reference features on the Earth is a spherical coordinate system called latitude and longitude. However, when a map is made, the spherical coordinates must be translated into a planar coordinate system via a process termed projection. Planar coordinate systems are used for most mapping because the mathematics are simplified. Projecting spherical coordinates of latitude and longitude into a flat x,y coordinate system causes certain distortions to occur in the data being mapped. MapInfo uses latitude and longitude coordinates which are projected into a cylindrical projection called Mercator and this coordinate system causes distance measurement errors and distortion of shape the further the place being mapped is north of the equator.

When mapping small regions, such as a county or city, a local plane coordinate system is often preferred, such as the State Plane Coordinate System (SPCS). SPCS is well suited for accurate distance measurements and is the choice of many surveyors. The map coordinate accuracy is about one foot in 15,000 feet for distance measurements. However, SPCS has is not easily extended over large regions because the curvature of the Earth (one foot in 300) which causes distance measurement errors to begin to accumulate. Therefore, the SPCS uses several zones to map larger regions such as a State. When one crosses from one zone to the next, the mapping coordinate system is likely to change thus counties bordering a different zone will have different coordinate systems and different methods of projection. This adversely impacts LDT dispatch because then each projection and coordinate system needs to be known before coordinates can be projected.

Another commonly used map coordinate system is the Universal Transverse Mercator (UTM). UTM is similar to SPCS but the zones are larger, and more importantly, the coordinate system is continuous from zone to zone thus features mapped in one zone can be easily referenced to features mapped in another zone. The distance measurement accuracy is more coarse than SPCS (about one meter accuracy), but perfectly acceptable 9-1-1 dispatch. UTM is a less popular coordinate system than SPCS among surveyors, but is much better suited to the layperson because of its superior human interface to determine map locations.

Conclusions

The Wireless Integration Project has resulted in a more accurate map to test the accuracy of wireless-call tracking location determination technologies. The improved mapping accuracy is necessary to accurately determine the effectiveness of LDTs as an emergency dispatch aid.

The WIP has also indicated that many more directions of research are required before dispatch mapping standards can be specified for wireless call tracking. Issues remain to define acceptable "error budgets" for LDTs and mapping. Human factors issues require research to determine how dispatchers can best utilize mapping for emergency call management.

Other directions for research stemming from this test include how low-cost automatic vehicle location AVL via cellular phone and personal communications systems may be implemented with location determination technologies. It is also conceivable that real-time emergency call routing is possible. This type emergency call routing will dramatically impact how today's 9-1-1 databases are created and maintained, probably resulting in less involvement in the provision of 9-1-1 services by telephone companies.

Other possibilities of coordinate-geocoding of emergency calls is the ability to map emergency incidents and track reported crimes in near real-time.

LDT is certain to have greater, unforeseen impact than these listed in this paper. It may be likely that LDT could revolutionize 9-1-1 services in rural communities across the nation struggling to improve the timely provision of 9-1-1 services because of poor mapping and addressing systems.

NORTEL
Derek Prada, Chris Ouellette

NORTEL provided both project leadership and project management to the WIP team.

In addition to Project Leadership and Telecom Consulting services, NORTEL provided

- VISIT ENR (Emergency Numbering Routing) CPE Workstation program changes
- Meridian 1 Option 61 Hardware and Software Enhancements
- MapInfo Programming and Integration with VISIT ENR Software
- Partial Funding of Video Documentation
- Facilitation of Video Production Crew
- Overall Project Management

NORTEL engineered the delivery of P-ANI using DNIS or dialed Number Information Services which enabled VISIT ENR to uniquely identify cellular 9-1-1 callers. VISIT ENR received the digital input on the Meridian M2616 phone set connected to the CPU. The system acknowledged the ANI which invoked a retrieval of the associated LAT/LONG and ESN data from the Wireless Selective Router SCC SR-ALI database. Data returned from the SR-ALI database and AGI processor were used as the keys for searching MAP/ALI data tables loaded on the PSAP workstation. This generated a process which displayed the street map of the cellular caller location, highlighted by the Level of Confidence circle. In addition, overlaid on the map was the cellular caller's ANI displaying using bold characters. This easy to recognize display was met with instant approval as the call takers had both the ANI and now the Map ALI representation which they had not previously seen.

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Wireless E 9-1-1 in the Garden State

by S. Robert Miller, Executive Director, NJ OETS

In mid 1996, the FCC took steps in support of Wireless E 9-1-1 and issued 94-102 rule making which called for wireless Automatic Number Identification (ANI) within 18 months and wireless Automatic Location Identification (ALI) within 5 years. This was supported by public safety agencies across the land. Two states, with the help of several vendors which have been strong supporters of the goals of NENA, set out to prove that Phase I (ANI in 18 months) and Phase II (ANI/ALI in five years) directives of 94-102 were not only possible to achieve technically, but could be achieved sooner - rather than later.

Within six months of the FCC's order, the States of Texas and New Jersey met the FCC's order for both Phase I and Phase II. The Lone Star State and the Garden State had slightly different goals and took different approaches which strengthened the position of NENA, APCO, and NASNA, (the "joint commenters") that the goals of 94-102 could be accomplished in a multiplicity of ways. This paper is about the wireless trials held in New Jersey.

The first wireless trial in the Garden State was held in October 1994. The project was formed and coordinated by the New Jersey Office of Emergency Telecommunications Services (OETS) and Bell Atlantic. Members of the project included: Rockwell, Smith Advanced Technology (SAT), OETS, Bell Atlantic, and the Gloucester County Communications Center. The project utilized the Global Positioning System (GPS) and SAT equipment. As test calls were initiated, SAT equipment uploaded the GPS information over the cell link to a SAT processor which plotted the caller and sent routing instructions and other location information to a Rockwell SCX 9-1-1 tandem.

The Rockwell SCX tandem routed the call to one of two PSAP positions established at the Gloucester County Communications Center in South Jersey. One position covered Gloucester County and the other position covered Philadelphia which is due west of Gloucester County and across the Delaware River. The system plotted the pseudo 9-1-1 test calls and displayed the caller's location, speed, and direction on a computer mapping terminal.

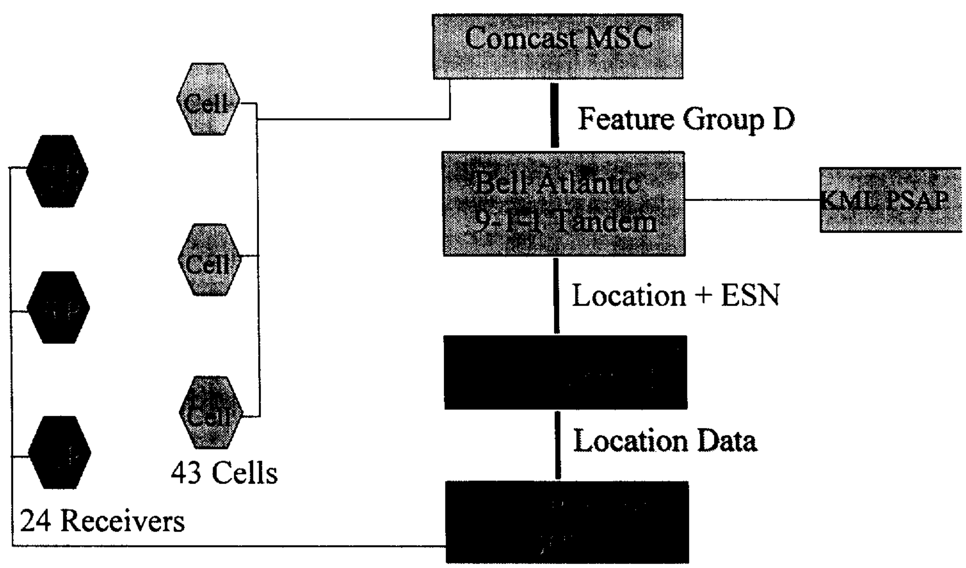
The trial used cellular mobile phones mounted in a vehicle coupled with a GPS receiver, both with roof- top mounted antennas. The system worked extremely well and the trial was a complete success. However, it is questionable whether this solution fills the total needs of today's society. Today, people are purchasing portable cellular and PCS phones in large numbers and using them inside buildings, trains and automobiles, etc. - places where GPS transmissions cannot be received.

In the spring of 1996, a second wireless project team was formed in the Garden State. This project was also coordinated by OETS and Bell Atlantic. Time Difference Of Arrival (TDOA) technology was selected for this project. The project partners are: the Associated Group, Comcast Cellular Communications, OETS, Bell Atlantic, Rockwell, KML, MapInfo, On-Target Mapping, QED, SCC Communications, and the Counties of Burlington, Camden, Gloucester, and Salem. In October, the Associated Group placed

24 *TruePosition*^{tm} TDOA receivers at Comcast Cellular sites in the New Jersey Turnpike/I-295 corridor and KML installed their enhanced PSAP terminals. This system has been tracking test calls since mid-November.

On January 22, 1997, the system will be turned up live for 9-1-1 calls. The location system covers 50 miles of the New Jersey Turnpike and I-295 corridor from the New Jersey/Delaware State border to Bordentown which is just south of Trenton, the State Capital (see figure 1). Unlike the previous trial, the system does not require modifications to existing cellular phones nor does it require a clear view of several GPS satellites. The receivers are connected via Comcast data links to a *TruePosition*^{tm} Signal Collection System (SCS) which calculates the 9-1-1 caller's location, nominally, within 125 meters 67 percent of the time (see figure 2). At other times, the resolution will be greater or less

New Jersey Wireless Location Trial



than 125 meters. The information is then passed to a SCC Communications SR/ALI computer.

The SCC SR/ALI computer determines the Emergency Service Number (ESN) of the wireless caller based on the latitude and longitude of the caller and dynamically creates Selective Routing (SR) and ALI records. The call arrives at the Rockwell SCX 9-1-1 tandem on "Feature Group D" (FGD) trunks from the cellular Mobile Switching Office (MSO). The SCX 9-1-1 tandem then queries the SCC computer for the ESN and ALI information. The SCC computer sends the ESN, latitude/longitude, speed, and direction of the caller to one of New Jersey's three Rockwell 9-1-1 tandems over data links.

The Rockwell 9-1-1 tandem routes the call based on the ESN received from the SCC computer. The Rockwell tandem then sends the ANI, ALI (latitude/longitude), direction, and speed of the caller to the PSAP. This is accomplished over the standard PSAP circuits which are used for wireline calls. No additional circuits are needed to the PSAP for the wireless calls.

The 9-1-1 calls are answered at the PSAP with KML (advanced Rockwell IPSAP) terminals with mapping software developed by MapInfo and On-Target Mapping with the assistance of QED. The New Jersey Master Street Address Guide (MSAG) data was created graphically, and maps with the Emergency Service Zones (ESZs), are available statewide. The KML terminals display a standard type ALI screen formatted for wireless data.

New Jersey Wireless Location Trial

TruePosition ANI/ALI		
609-342-5678	09:30:25	01-22-97
COMCAST CELLULAR COMMUNICATIONS		
000000	U S ROUTE 40 RT	
RADIUS 5 MILES		
ELMER BORO		XX
39-35-51N 75-10-28W		
DIR 124 SPEED 048		CELL
ROAM NO 302-740-7626		ESN 5397
SALEM COUNTY COMMUNICATIONS		
ELMER POLICE DEPT		935-0057
ELMER FIRE DEPT ST-21		358-8881
ELMER AMBULANCE		358-8881

The terminals display the cell site, roam access number, calling party ANI, ALI in latitude/longitude, speed, direction, and the emergency service providers (police, fire, EMS). The terminals then map the wireless call utilizing MapInfo and On-Target software. The same PSAP terminals can be used for wireline calls and can display maps of those calls based on street addresses.

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Wireless Integration Project - Engineering Economic Analysis

Overview

One of the most significant results of the efforts of the Texas Wireless integration project is an appreciation of the number of ways that the wireless problem can be solved. The project provided a rather in-depth appreciation that :

- Technology is now available to solve the problem.
- Not all PSAP's needs are the same.
- Regional Economics will be a major factor in determining Wireless 911 service levels that are appropriate for differing regional demographics.

This portion of the project's documentation is intended to provide insight into understanding the relationship between economics and technology as it relates to implementing a solution for locating the wireless 911 caller. It is relatively easy to be overwhelmed by the complexity, uncertainty, and volume of interrelated variables. Half the battle lies in establishing an approach to the problem and the scope of the answers....."Are we in the right ballpark?" is a key concern of the analysis.

The intent of the WIP engineering economic analysis is to establish a model that can be easily modified (as more accurate data and modeling assumptions become available) to provide output that can be useful in the strategic planning process. The exercise has resulted in a ten plus page spreadsheet that can be easily adapted to provide informative insight and output. All efforts have been made to present the data in as simple and useful a format as possible. And by the way.....Yes! The numbers strongly suggest that technical solutions are not only possible, but appear to be economically viable, and well within the funding means currently being considered by 911 planning agencies across the United States

The 911 Catch 22

911 planner	"How much for a wireless 911 solution?
Svc provider	"Depends on what you want"
911 planner	"Well, what do you have?"
Svc provider	"Nothing off the shelf we're still working on standards"
911 planner	"Well , what do you plan to offer?"
Svc provider	"Don't know, the technology is still being developed.....How much do you have to spend?"
911 planner	"Don't know... depends on what you're going to charge me......to get money I need to explain what I'm going to get for it"
Svc provider	"Well I don't know what we're going to charge .... 911 people all want something different, and you always want it for nothing......why don't you all get together and tell me what you want and how much you have to spend"
911 planner	"But I can't tell you what I want unless you tell me what can be done and at what cost.....so .... How much for a wireless 911 solution? "

While the above is a gross simplification of the wireless paradigm, certainly one of the objectives of the Texas WIP project is to help break the wireless 911 "catch 22". Our goal is to help provide insight and understanding to help address the 911 planner's first dilemma .....How do we establish wireless 911 service level objectives, that are within our region's funding means, when no-one can tell me what the services will cost?

The following analysis is not intended to provide definitive answers to this and related questions, but rather to provide broad gauged answers, planning tools, and a foundation of knowledge that can be built upon to help 911 planners and service providers implement wireless 911 solutions.

The first step to breaking the "catch 22" cycle is to clearly define the levels of wireless 911 service. We need to understand the starting point, the options available, how much money is available, and a rough understanding of what it will cost to implement the various options.

One practical way to deal with the complexity and the number of variables, is to approach the problem in a systematic but iterative way, using the broad gauged answers to keep the planning process moving forward, while revisiting assumptions and estimates as better data becomes available at each step of the implementation process.

The money's in the bag!!

That old adage "Where there's a will there's a way", has provided many with the internal strength and fortitude to succeed against impossible odds. While it may be a sad reflection on our society, whomever captured these words of inspiration surely underestimated a key ingredient in finding "a way".

Surprise, surprise !! We begin the analysis by assuming that someone will pay for the incremental service required to implement wireless 911. We assume that Joe public would not appreciate wireline based 911 service fees subsidizing the implementation of 911 services for wireless users. For simplification, we assume that the wireless subscriber would pay for an "overlaid" implementation of wireless 911 service on the existing wireline infrastructure.

The impact of this statement should be carefully considered when interpreting this analysis, because unfortunately, nothing is ever so simple. It is impossible (or very difficult) to develop a model that is truly an incremental wireless model. The wireless caller will inevitably utilize and take advantage of the huge infrastructure of calltakers, equipment, operations and maintenance resources that are currently in place for wireline 911 service.

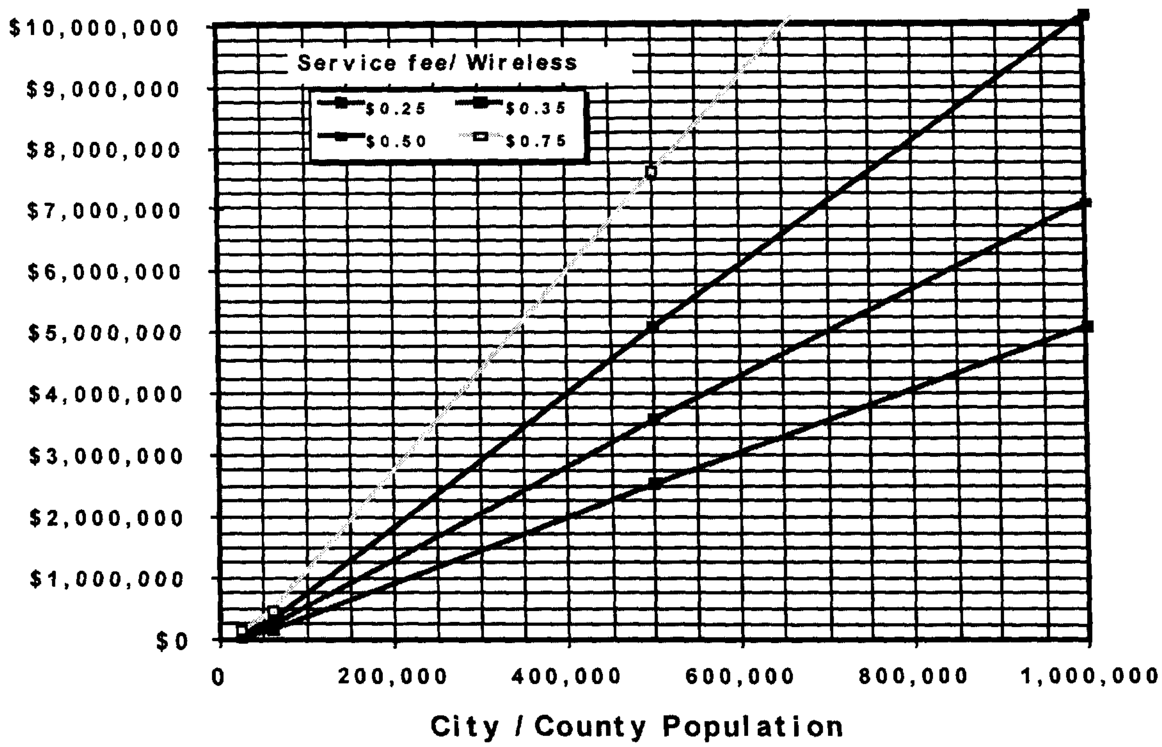
At the same time, we all appreciate that the wireline 911 environment is under tremendous pressure to upgrade technology due to factors that are considered "non wireless". For example: wireline Local access competition, Local number portability, and NPA exhaustion to name a few. Each of these factors require that 911 systems provide 10 digit callback, more sophisticated Network signaling and/or intelligence

(CCS7, PRI, and/or Advanced intelligent Networks) to deal with the new demands that these forces will place on 911 data delivery, data management , and call routing.

The wireline environment therefore stands to benefit from the implementation of technology for the wireless 911 caller, technology that will help address these "non wireless" issues. We believe that it would be unnecessarily complex a task at this point to attempt to model a truly incremental economic model that fully separates these cross subsidies. This issue is important to appreciate in our discussion and assumptions in creating the costing model.

Fortunately, if we can all agree that the wireless subscriber <u>will pay</u> to be able to dial 911, and be routed to a suitable public safety answering position then the first step is relatively easy.

<u>Figure 1 - Available funds - 5 yr view</u>



Reference to fig. 1 shows the available funds that would be generated over 5 years for given County or City sizes, given different levels of wireless 911 service fees. We assume that the wireless base of subscribers is 10% of the population in year 1 for rural environments, and 20% in Urban environments. The wireless growth rate is 30% in years 1 & 2 and 20% per annum in years 3,4 and 5. We assume that regional population grows at a rate of 3% per year, and that the largest number of wireless roamers at any given time is 5% of the wireless base.